TIME CONTROL

OF

STREET LIGHTING

AND

OFF-PEAK WATER HEATING

WITH

CARRIER CURRENT

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GENERAL ELECTRIC

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GENERAL ELECTRIC COMPANY

SCHENECTADY, N. Y.

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TIME CONTROL
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The advantages of controlling street lights and domestic off-peak loads directly at the distribution substation have long been recognized, but the adoption of multiple street-lighting systems has been greatly retarded by the excessive cost of pilot wires and by the inherent operating disadvantages of other, less costly forms of control.

The desirable improvement of system load factor and the resulting increase in revenue available through active promotion of domestic off-peak loads, such as water heaters, have also to a considerable extent awaited a simple and economical means of turning on and off such loads directly at the distribution substation.

The far-reaching possibilities of a practical system of control based on the pilot-wire principle, but without the necessity of using pilot wires, have led the General Electric Company to seek a solution of this problem.

The solution finally developed—designated as CARRIER-CURRENT CONTROL—has proved under actual operating conditions that this system of control is entirely practical. The system has been proved sound in principle; it involves apparatus fundamentally simple in design; and in operation it offers many distinct advantages with practically none of the weaknesses inherent in other forms of control.

In the field of street lighting, it permits the use in combination of both the multiple and the series systems, and therefore the decision as to which type of lighting should be used in various parts of a city need no longer be as strongly influenced by the problem of control as formerly.

In the case of domestic off-peak loads, the use of this system of control often permits the application of smaller water heaters without reducing the available supply of hot water to the consumer, and therefore without reducing the power company's revenue. This is due to the fact that the heavy Saturday, Sunday, and Monday demand for hot water can be taken care of by charging all heaters more hours in each twenty-four between Saturday noon and Monday morning than is normally possible during the week. Likewise, the hours of charging during the week are under the direct control of the distribution substation attendant, making it possible to de-energize all off-peak loads upon the approach of both normal and UNEXPECTED peak-load periods. In localities where the distributing utility purchases or exchanges power on a maximum-demand penalty basis, this feature alone offers yearly savings equivalent to an appreciable percentage of the total cost of the control installation. Other important advantages of this system of control, when used with off-peak loads, are low maintenance, long life, and absolute freedom from cumulative effects due to power outages.

The General Electric system of carrier-current control incorporates such outstanding features as:

(1) Complete control, directly at the distribution substation, of series and multiple street lights, off-peak water heaters, off-peak house heaters, sign lights, show-window lighting, distribution circuit breakers, or other groups of distribution loads.

(2) Number of controllers—total load to be controlled—practically unlimited.

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(3) One transmitter can be used to control two distinct groups of loads. In the case of all-night and part-night lighting schedules, three groups can be controlled.

(4) Simple to operate. Push-button or full-automatic control.

(5) Low maintenance. Transmitter and controllers operate only when loads are being opened or closed.

(6) No pilot wires or other outdoor control wiring. Easy and economical to expand as conditions require.

(7) Inexpensive to operate. Practically no power consumed except while controllers are being opened and closed.

(8) No readjusting necessary because of power interruptions or changes in lighting or off-peak schedules.

(9) Exceptional reliability.

PRINCIPLE OF OPERATION—At the distribution substation, a motor-alternator feeds carrier current of 480 to 720 cycles, or both, into the station bus. This superimposed control energy travels through the feeder regulators and along the feeders, and then is stepped down to the 115-volt secondary circuits by the distribution transformers in essentially the same manner as the 60-cycle power voltage. At desired points along the 115-volt secondary circuits, tuned relays respond directly to the 480- or 720-cycle carrier current. On a carrier impulse of approximately 10 seconds, the load contactors controlled by these tuned relays close the load circuit, and open them on an impulse of approximately 35 seconds.

In practice, operation can be effected simply by pressing an "on" an or "off" push-button at the distribution substation. When it is desired to open or close a group of loads, the proper button is pressed, causing the motor-alternator to start. After sufficient time has elapsed to assure that the motor has attained normal speed, the high-frequency voltage is impressed upon the feeder circuits for the proper time interval, after which the equipment automatically shuts down.

The voltage impressed upon the distribution feeders depends upon the ratio of the feeder voltage to the secondary voltage. For 2300-volt feeders and 115-volt secondaries, the impressed voltage on the feeder is approximately 100 volts, corresponding to 5 volts maximum on the 115-volt secondaries. This control voltage does not, however, add directly to the rms. power voltage. By adding 5 volts of carrier control energy, the total secondary voltage is raised approximately 0.113 volt rms., which is less than 0.1 of one per cent increase. In practice, losses in transmitting and in transforming the carrier energy reduce this voltage from a theoretical 5 volts to approximately 3 volts, corresponding to an over-all increase of less than 0.10 volt rms.

APPLICATION—This system of control can be applied to practically any distribution network, whether of underground or overhead construction, or a combination of both.

The rating and arrangement of the transmitter equipment depend on the extent and complexity of the distribution network to be energized and, in a small degree, upon the number of controllers involved. For average substation areas, the output requirements are approximately one twelve-hundredth of the substation capacity.

The transmitter and control equipment can be arranged to energize successively each phase of the substation feeder bus or, in the case of primary street-light control, all controllers can be placed on the same phase of the 115-volt secondaries and thus permit a simplification of the transmitter control apparatus.

With the transmitter coupled to the substation feeder bus, the reactance of the station transformer prevents serious energy loss into other parts of the system. In this way, independent control of the loads in each substation area can be obtained. However, where a number of distribution substations are metallicly interconnected by a higher-voltage distribution system, a single large transmitter can sometimes be applied to the higher-voltage line more economically than equipping each of the distribution substations with individual transmitters. Factors which determine the most suitable arrangement of the transmitter apparatus are listed on the last two pages, the data called for being necessary to arrive at a practical and economical solution of a given problem.

The application of controllers offers no difficulties except in unusual problems. General application precautions are listed below under EQUIPMENT.

EQUIPMENT—A block diagram of the complete control system is shown on print H-4942394.

THE TRANSMITTER EQUIPMENT consists of a motor-alternator of 480 or 720 cycles output, or both, a master control panel and contactor panel, a high-frequency output transformer, tuning inductance, and coupling capacitor (see Photo. No. 478958). Low-capacity breakers or contactors are used to connect the transmitter to the three phases of the feeder bus successively, to a single feeder, or to all three phases simultaneously, depending on the specific arrangement of the transmitter equipment. Diagram H-4942394 shows the single-phase arrangement using three single-phase breakers interlocked to provide successive excitation of each phase of the feeder bus. For three-phase (simultaneous) excitation of the feeder bus, one three-phase breaker replaces the three single-phase units, and three coupling capacitors are used instead of only one as a means of coupling the alternator to the line.

The master control panel contains the timing relays, interlocks, etc., necessary for push-button or full-automatic control.

The high-frequency output transformer, with tapped secondary, serves to couple the alternator to the tuned output circuit, and to provide a means of adjusting the output of the carrier-current alternator.

The coupling capacitor operates both as a high impedance against the power-frequency voltage and as the necessary electrostatic capacity to resonate the output circuit at 480 or 720 cycles, or both. This unit consists of standard power-factor-improvement capacitors, connected in a series-parallel arrangement to provide the necessary voltage and capacity rating.

The tuning inductance consists of an insulated, stranded copper conductor wound on a treated-wood support, designed to assure low losses and convenient installation and adjustment.

The transmitter equipment operates from any standard 3-phase power supply, and from 125 volts direct current. The a-c. supply driving the motor-alternator should not vary more than 10 per cent plus or minus during operation of the equipment. The 125-volt d-c. supply is used for operation of the oil circuit breakers or contactors, and for alternator field excitation.

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The controllers are available in two different designs, one for street-light control and another for the control of domestic off-peak loads. Both respond to the same "on" and "off" timing impulses so that the same transmitter can be used to actuate both types. However, in order to maintain independent time schedules, each type is designed to operate at a frequency differing from the other. A frequency of 480 cycles is usually employed for street-light control and 720 cycles for domestic off-peak load control.

THE STREET-LIGHT CONTROLLER is shown on Photo. 482844 and Connection Print H-4948115. The load contact mechanism on this unit can be modified to accommodate an all-night, part-night lighting schedule on the same control frequency without restricting the use also of the same transmitter for domestic off-peak load control. The following explanation of the operation of this controller, however, is restricted to the type adapted to an all-night lighting schedule, as the part-night type simply employs a differently shaped motoring cam.

Referring to print H-4948115, the high-frequency input circuit of the controller consists of a capacitor and a reactor tuned to 480 cycles. When carrier current of this frequency is received, a portion of the control energy available in this circuit is rectified by the copper-oxide rectifiers to actuate directly, without amplification, a direct-current relay of standard telephone design. The contacts of this magnetic relay energize the synchronous motor of the contactor mechanism, causing the double cam to revolve at a speed of one revolution per minute as long as carrier current of the proper frequency is received.

Starting from the normal "off" position shown on the print, a 480-cycle impulse of 10 seconds duration causes the cam to revolve clockwise until, within approximately 5 seconds, the upper load contact snaps up from level "A" to level "B," thus closing the load circuit. At the end of the 10-second impulse, the synchronous motor is deenergized by the opening of the magnetic relay contacts, and therefore the load contacts remain closed.

To open the load contacts, an impulse of 35 seconds instead of 10 seconds duration is sent out by the transmitter. This impulse is sufficiently long to rotate the cam to a point where portion "D" of the motoring cam first closes the lower or motoring contacts, and then portion "B" opens the upper or load contacts. At the end of the 35-second impulse, the magnetic relay opens, but because the lower contacts of the load contactor mechanism continue to energize the synchronous motor, the cam continues to rotate until level "C" of the motoring cam opens the motoring contacts. The cam then comes to rest in the position shown on the print, and the load contacts remain open.

This motoring or "resynchronizing" feature prevents small variations in timing, starting speed of motors, etc., from causing false operation of the controllers. The "off" impulse of 35 seconds also assures that each controller will come to rest at the normal "off" position, regardless of the position of the cam at the beginning of the "off" transmitter impulse. Cumulative errors are therefore prevented, and critical timing adjustments are made unnecessary.

This controller operates on a minimum of 1 volt at 480 cycles, and a 60-cycle power supply of from 100 to 150 volts. The selectivity of the input circuit is such that operation is unaffected by 720-cycle energy. Mechanical vibration caused by street traffic, and temperature variations of from minus 40 to plus 125 degrees Fahrenheit will not cause false operation. The silver load

contacts are designed for an incandescent-lamp load of 10 amperes at 115 volts alternating current.

Internal construction is illustrated on Photo. 482844. The chassis and the enclosing case are brass, dull nickel finish. The case, built on the "diving-bell" principle, permits temporary submersion of the controller without affecting operation. Line and load terminals, fuse, and hand-operation switch are accessible without removing the case.

Mounting lugs and dimensions are such that the unit can be mounted outdoors on a lamp post or in the base of a street-light standard. The mounting lugs accommodate a single bayonet catch at the top and a locking screw at the bottom. Approximate over-all dimensions are 4 by 15 by 4 inches deep. Approximate net weight is 10 lb.

THE DOMESTIC OFF-PEAK LOAD CONTROLLER is shown on Photo. 479237 and Connection Print H-4941441. The high-frequency input circuit and magnetic relay operate as explained above for the street-light controller. The input circuit of this unit, however, is tuned to 720 instead of 480 cycles, so that the control schedules of street lights and of domestic off-peak loads may be independent of each other.

Referring to Print H-4941441, the load contactor mechanism consists of a main and a trigger thermal strip, both of bi-metallic material, which deflect to the right and upward respectively when heated by their individual heaters. These thermal strips operate as follows:

Starting from the normal "on" position shown on the print, a 720-cycle impulse of 35 seconds causes the magnetic relay contacts to impress 115 volts across the main heater. The heat from this heater causes the main thermal strip to deflect to the right until, within approximately 25 seconds, it opens the load contacts and permits the trigger thermal strip to snap down. At the end of the 35-second impulse, the main thermal strip cools and returns to the left until it comes to rest against the edge of the trigger thermal strip. The load contacts therefore remain open, and because of the restoring pressure of the main thermal strip, the trigger contacts are forced to the closed position, thus preparing the mechanism for an "on" operation.

To close the load contacts, an impulse of 10 seconds duration is transmitted. The contacts of the magnetic relay now impress 115 volts across the main heater as before, but now also across the trigger heater through the circuit consisting of the main thermal strip, the trigger contacts, and the trigger thermal strip. Both thermal strips begin to heat, but since the small trigger thermal strip heats approximately eight times as fast as the larger and heavier main thermal strip, the former moves upward until, within approximately 5 seconds, it permits the main thermal strip to snap to the left, thus closing the load contacts and opening the trigger heater circuit. Both strips are then in the position shown on the print, and since the trigger heater is now de-energized, and the main thermal strip is insufficiently heated at the end of the 10-second impulse to deflect to the right, the load contacts remain closed.

Notice that regardless of the position of the load contacts, a 10-second impulse always leaves the contacts in the closed position, and an impulse of 35 seconds always causes the load contacts to open and remain open.

The domestic off-peak-load controller operates on a minimum of 1 volt at 720 cycles, and a power supply of from 105 to 125 volts. The selectivity of the input circuit is such that operation is unaffected by 480-cycle energy. Mechanical vibration, and temperature variations of from zero to 120 degrees Fahrenheit will not cause false operation. The silver load contacts are de-

signed for a heater load of 15 amperes at 230 volts alternating current. Either a 115- or 230-volt load can be controlled, but in either case 115 volts is required as a power supply for the controller mechanism.

Internal construction is shown on Photo. 479237. All component parts are mounted on a base plate of sheet steel, fitted with flanges and two sealing studs with wing nuts to assure a tight fit of the spun-metal cover. The design and arrangement of the component units facilitate visual inspection and routine testing. Three leads, color-coded to identify line and load connections, are brought out through a length of BX cable to facilitate connecting to line and load through a nearby junction box. Two holes at diagonally opposite corners of the base plate provide a convenient mounting arrangement and prevent tampering when the cover is sealed. Approximate over-all dimensions are 8 by 4.75 by 2.25 in. Approximate net weight is 3.5 lb.

MAINTENANCE—The transmitter equipment requires only a small amount of maintenance because of the intermittent, short-time character of the duty cycle. Occasional inspection and cleaning of the motor-alternator, relays, and contactors will maintain the transmitter equipment at a high degree of efficiency.

Maintenance of the controllers is normally restricted to investigation of actual failures. The small number of moving parts and the simplicity and strength of all component units are conducive to a system of control which is reliable, economical, and low in maintenance. Accelerated operating tests equivalent to between 30 and 50 years of normal use have been made without a single case of failure, and without undue wear of the moving parts involved. The operating record of a large public utility, covering the first ten months of regular operation (February 1 to December 1), shows a total of approximately 285,000 controller operations with failures from all causes of less than 47 thousandths of 1 per cent. For the last two months of this period, failures were less than 23 thousandths of 1 per cent.

The significance of this record is increased by the fact that this particular utility records two consecutive failures before taking a controller out of service for inspection.

QUESTIONNAIRE

NAME OF COMPANY..

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1. What type of street lights and what type off-peak power devices are to be controlled; that is, series or multiple street lights, house heaters or water heaters, etc.? Give data on voltage, and current consumed.

2. How many controllers are required? Are all controllers to be controlled at the same time?

3. Are controllers to be mounted indoors or outdoors?
Are controllers to be installed on cable secondaries, overhead secondaries, or both?

4. Are 115-volt secondaries available at all controller locations? Are secondaries two-wire or three-wire?

Questions 5–18 below should be answered for each substation area in which control is desired.

5. Is station attended? If it is unattended, is operation automatic or supervisory controlled?

6. Approximately how many controllers would be required in each substation area?

7. What is voltage of bus; frequency; number of phases?

8. Voltage, kv-a., and per cent reactance of transformer bank supplying bus. Are transformers connected star or delta? If star, is neutral grounded? How much additional transformer kv-a. should be considered?

9. A map should be furnished of the transmission system metallicly connected to the high-voltage side of the substation transformer banks, showing approximate lengths of cable and overhead lines, rating, and per cent reactance of transformers and generators metallicly connected to this system.

10. Are power-factor-correction capacitors located anywhere on system? If so, give particulars, including location and capacity.

11. Is a source of 125 volts direct current available in substation for operation of oil circuit breakers and control equipment?

12. Is a three-phase station-service transformer bank available as a power supply for the induction motor? If so, give voltage and kv-a. rating.

13. Should the oil circuit breakers used for connecting the coupling capacitors to the bus be provided with tripping in order to protect the power system against possible failure of the

coupling capacitors, or is a station service breaker or the equivalent available to provide this protection?

14. A print should be furnished showing layout of substation, number of feeders, and per cent rating of regulators and per cent reactance of current-limiting reactors.

15. What is present station peak load, and what should be considered the future station peak load?

16. Current and voltage rating of feeders?

17. Number of conductors?

18. Are feeders star or delta connected?

19. Are feeders cable, overhead, or combination of both?

20. Give length to most remote point on longest feeder.

21. If control in more than one distribution substation area is desired, and these substations are fed from an interconnected transmission system, it may be possible to connect a central transmitter to the interconnecting line and thus control all substation areas from a central point. If this is permissible or desired, include in information requested under point 9 the size and spacing of the interconnecting line conductors, and details of the next-higher voltage transmission system similar to that called for under point 9 for the intermediate voltage system. Desirable locations for the central transmitter, considered from an operating standpoint, should be mentioned.

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April, 1932 (1M)

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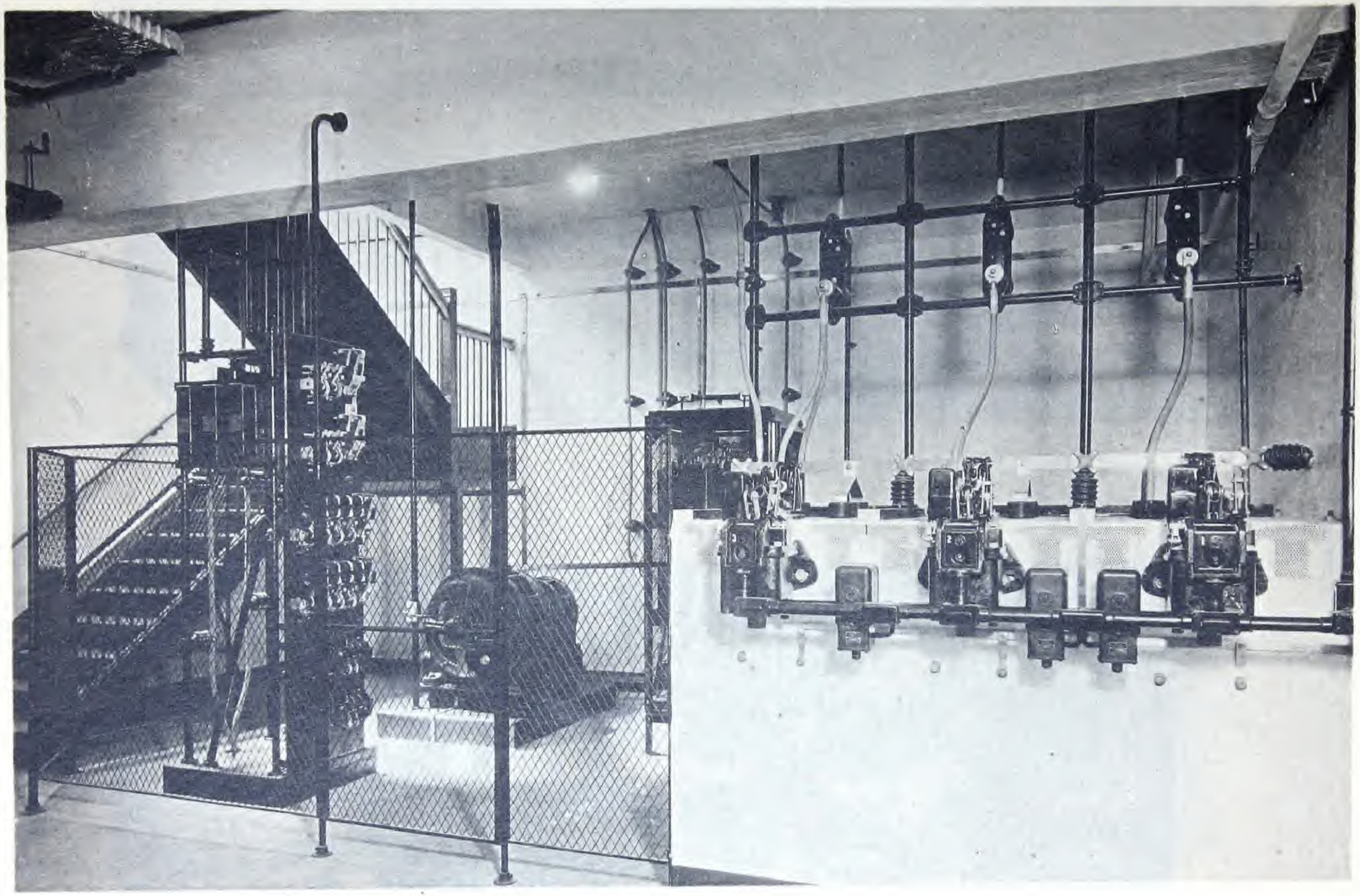

47 8958 G-E CARRIER-CURRENT TRANSMITTER FOR STREET-LIGHT CONTROL. SUBSTATION NO.7. UNITED ELECTRIC LIGHT CO., SPRINGFIELD, MASS.

654 E321 E323 7-6-31

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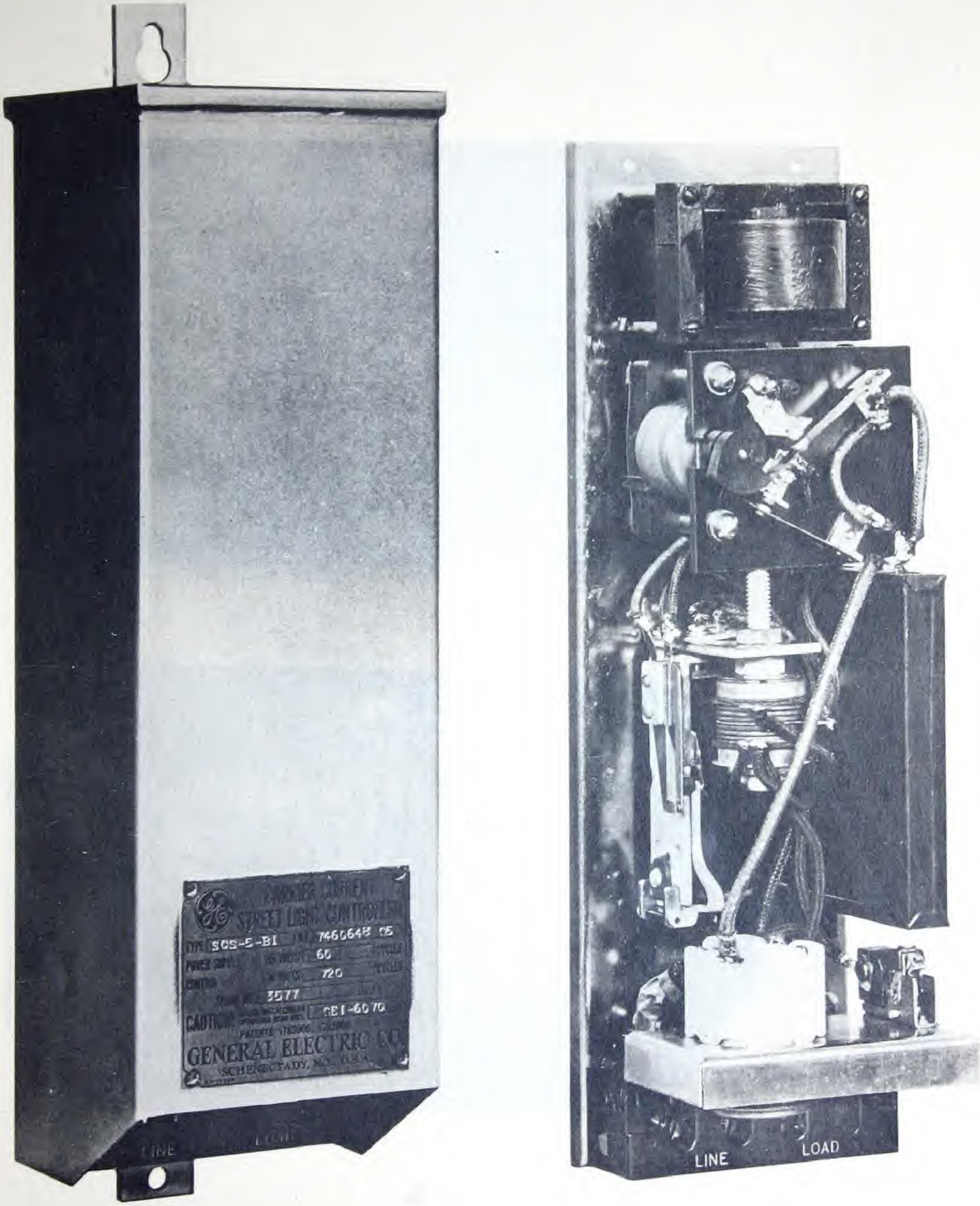
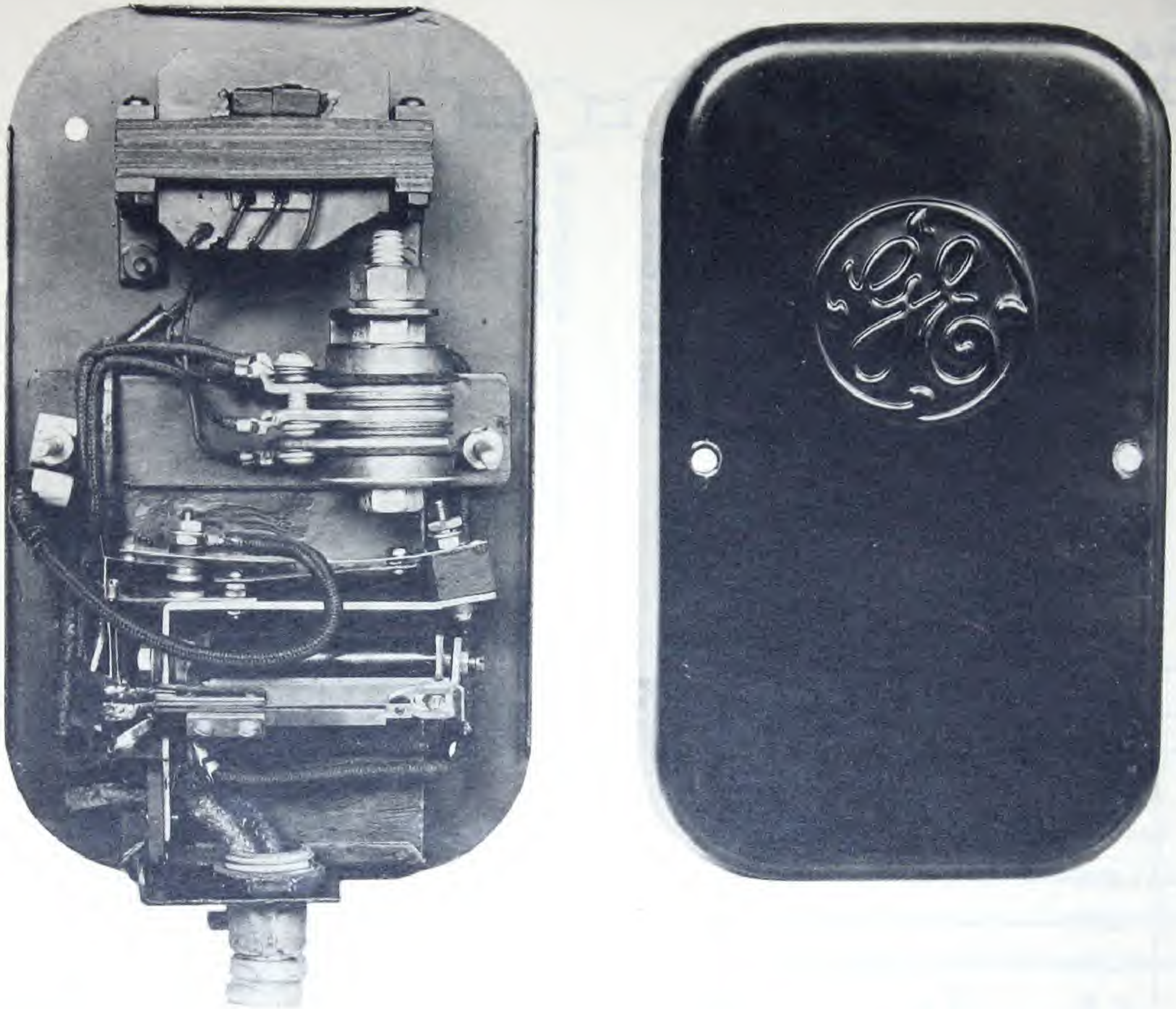


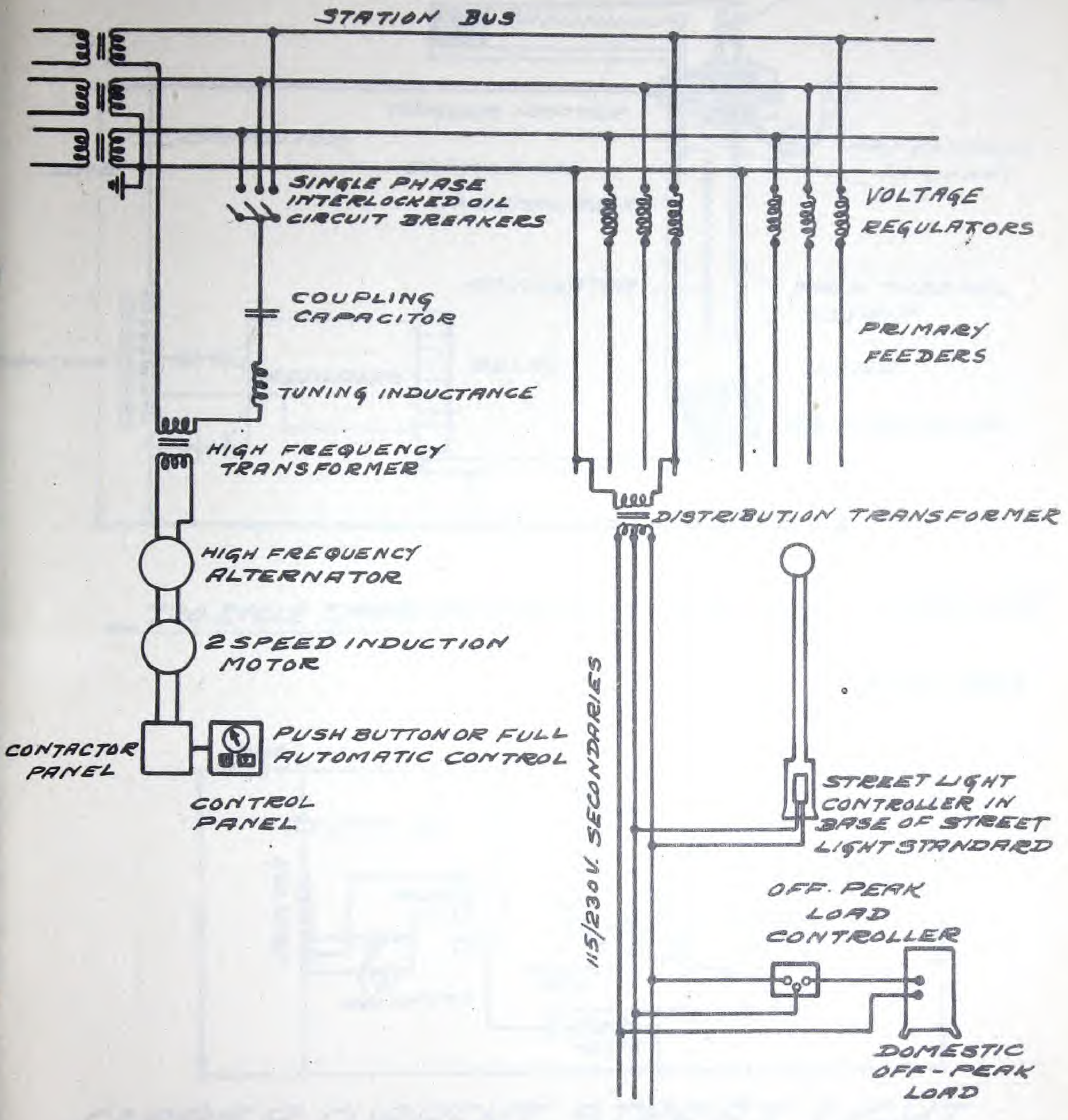
482844 G-E CARRIER-CURRENT STREET-LIGHT CONTROLLER, TYPE SCS-5-B1.

654 5-3-32



479237 CARRIER-CURRENT OFF-PEAK LOAD CONTROLLER TYPE SCS-5-C1
CONTROL 720 CYPS, LOAD 115/230 V., 15 A.

654 7-30-31



SHOWING SCHEMATICALLY THE CARRIER CURRENT CONTROL OF STREET LIGHTS AND OFF-PEAK LOADS

DEPARTMENT. RADIO. ENG.

W-4942394

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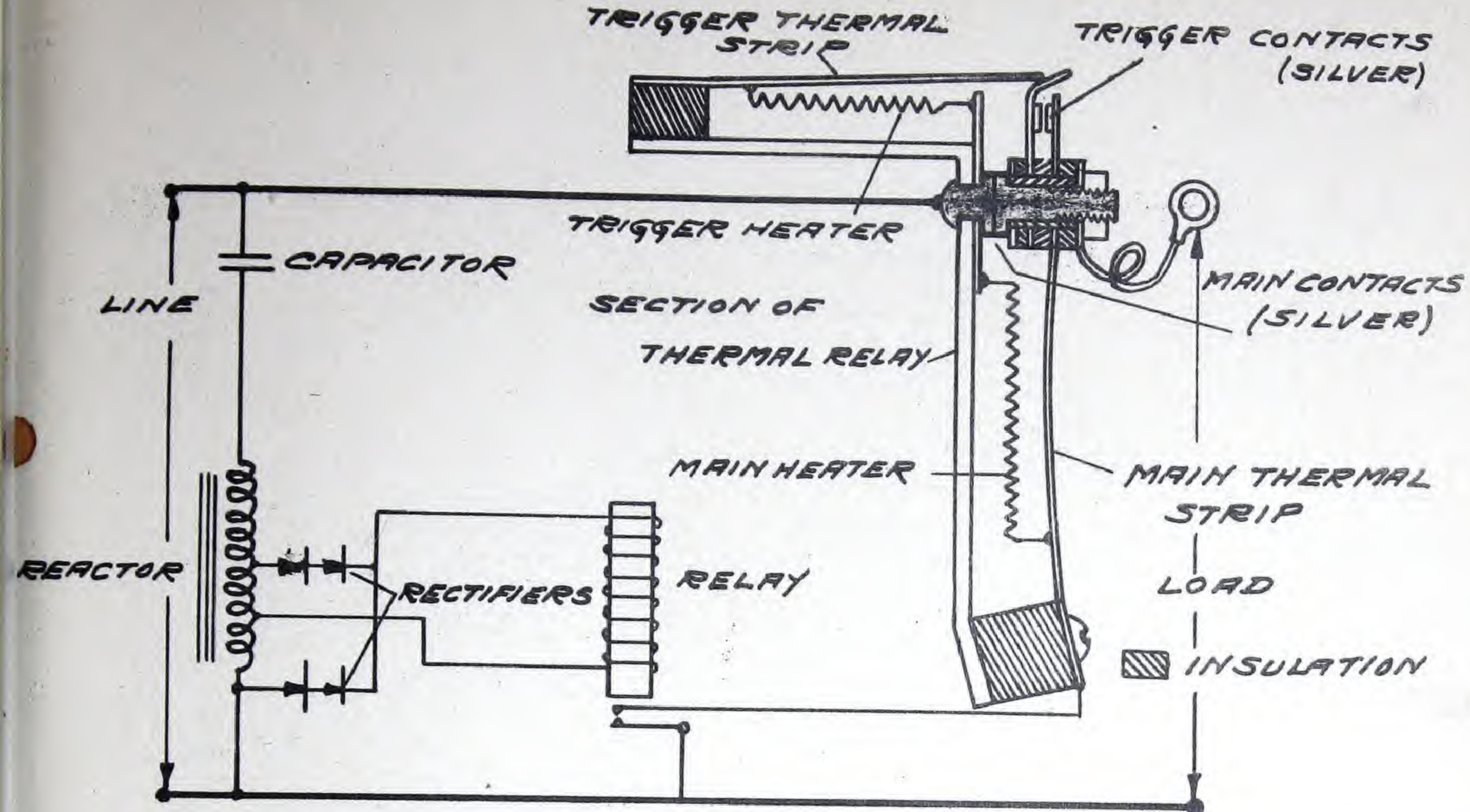
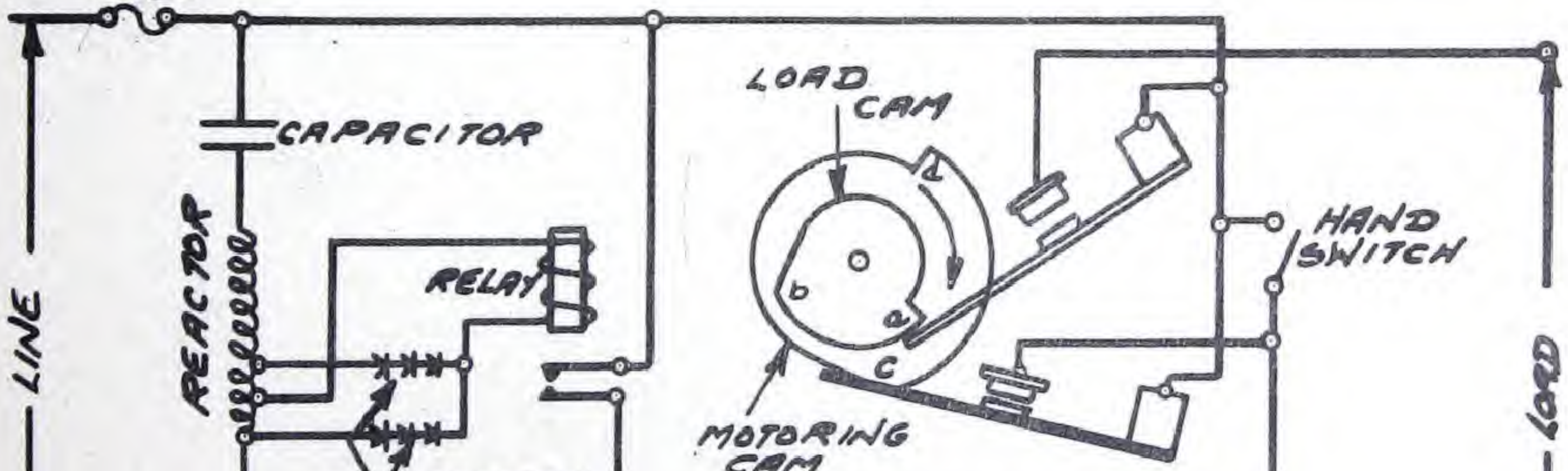


Title 720 CYCLE CARRIER CURRENT OFF-PEAK LOAD CONTROLLER.

H-4941441



CARRIER CURRENT STREET LIGHT CONTROLLER

H-4948115

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